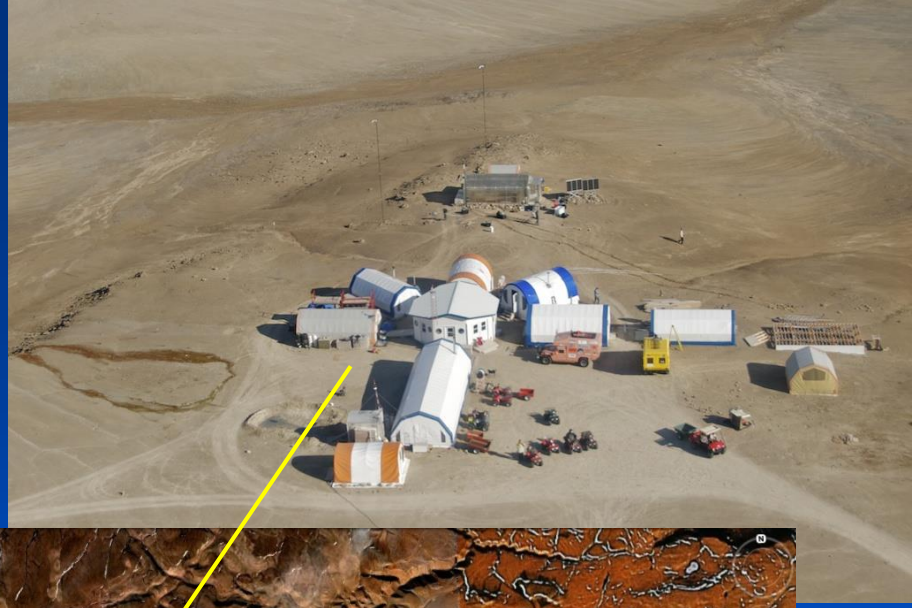
Low Dispersal of Human-Associated Microbes on to Pristine Snow during an Arctic Traverse on Sea Ice by the *Moon-1* Planetary Surface Rover

Dr. Andrew C. Schuerger[1] and Dr. Pascal Lee[2,3,4]

[1]Dept. of Plant Pathology, University of Florida
Space Life Sciences Lab, Kennedy Space Center, FL

[2]Mars Institute, [3]SETI Institute, [4]NASA Ames Research Center,
Moffett Field, CA

Haughton Mars Project (HMP)
1997-2015



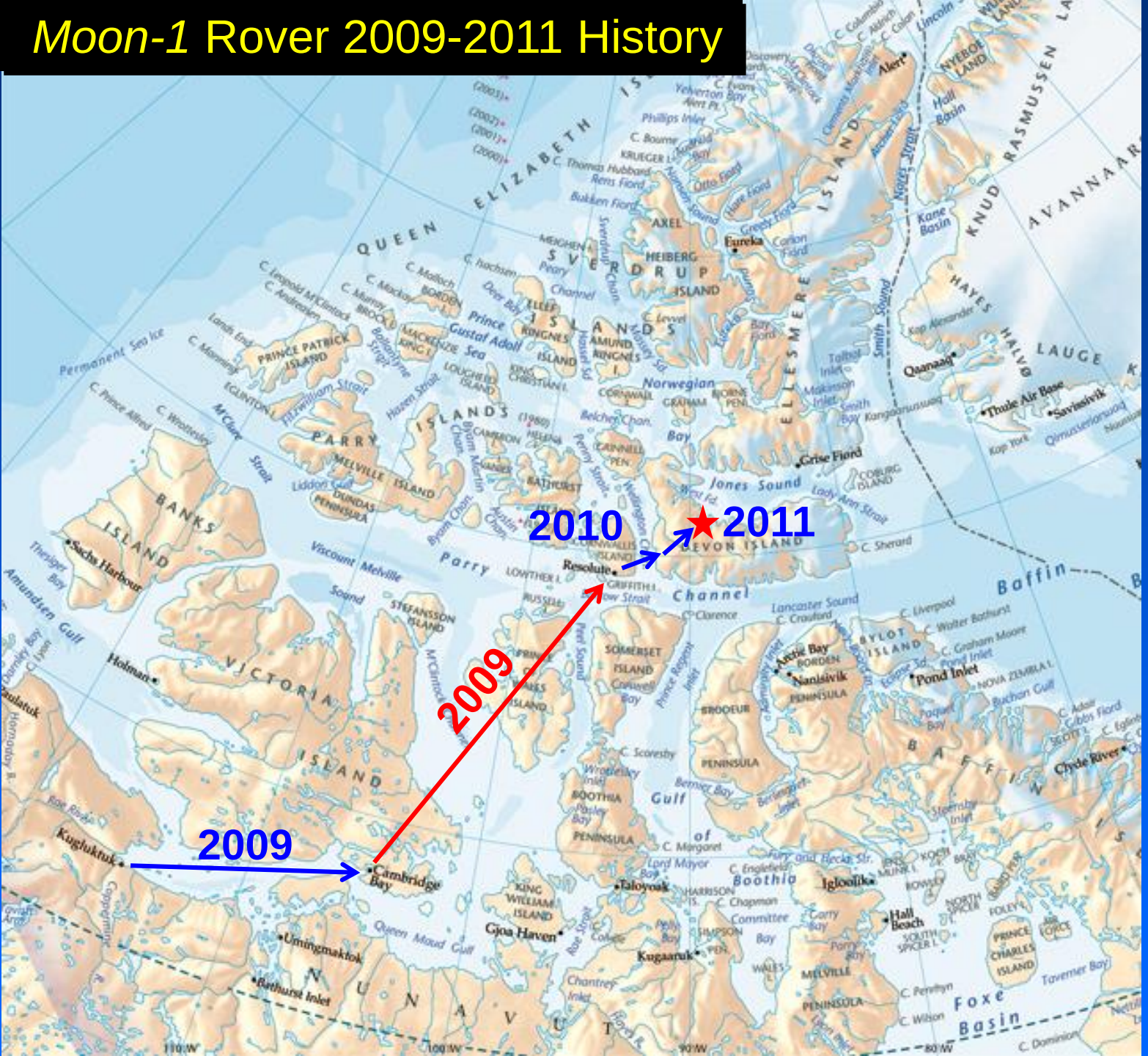
Moon-1 Rover 2009-2011 Travel History

= Flatbed truck

= *Moon-1* rover

= C-130 airlift

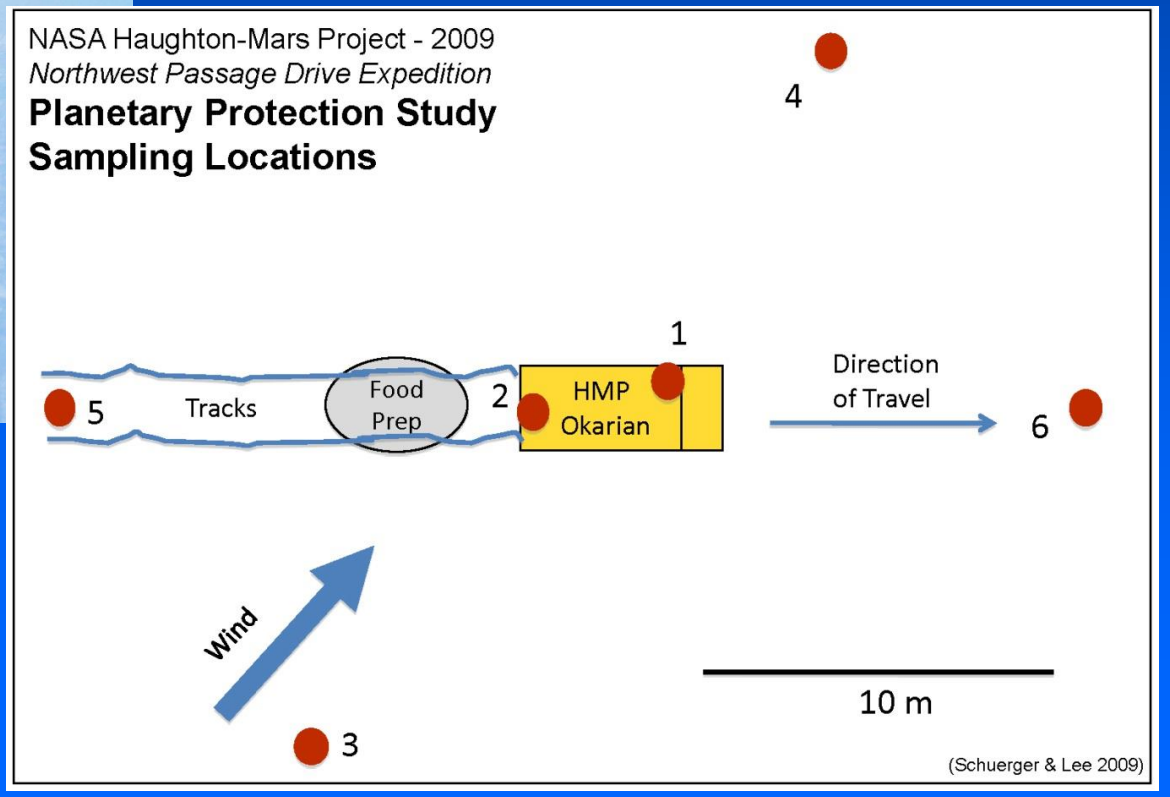
Moon-1 Rover 2009-2011 History



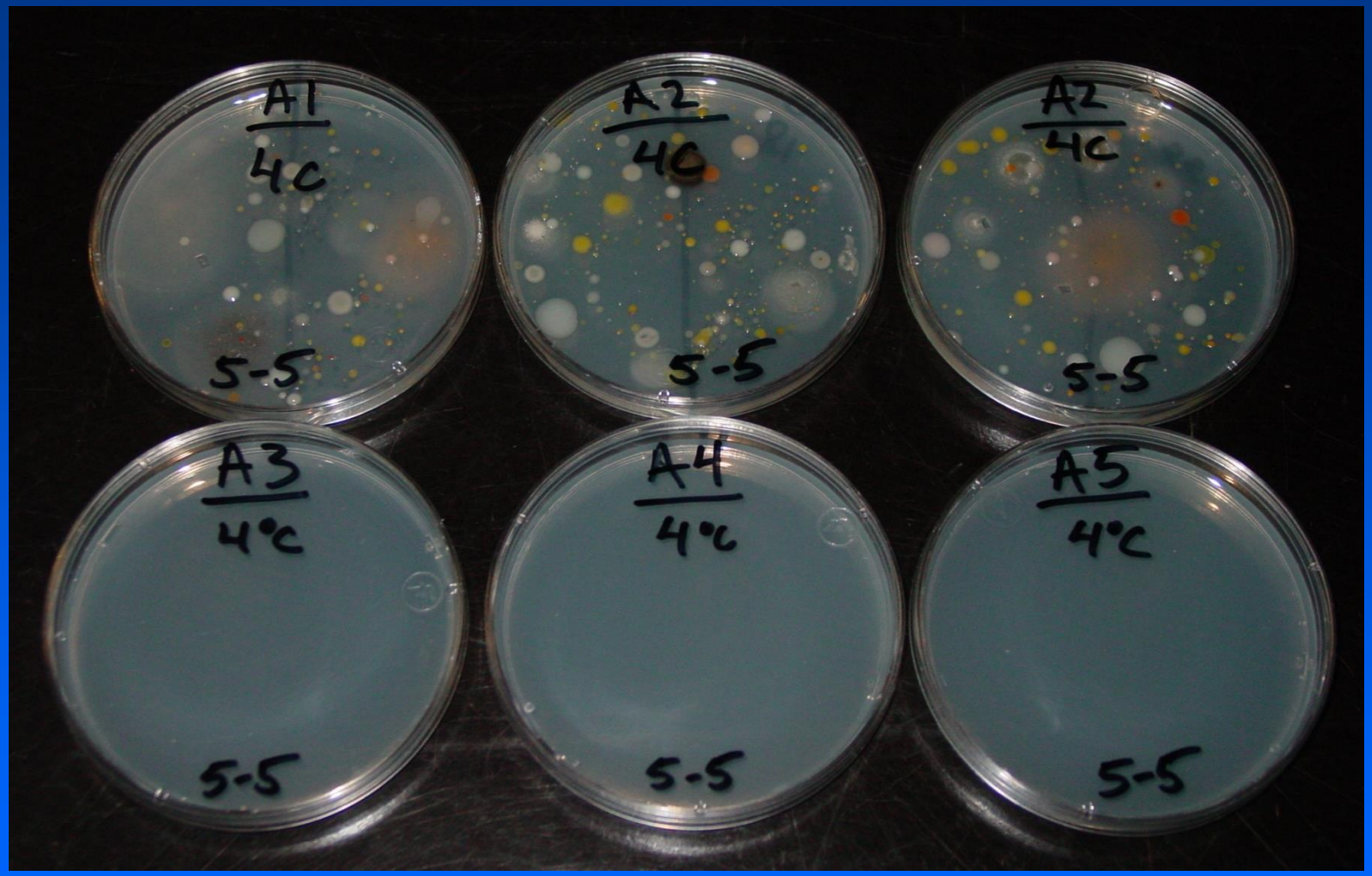
HMP Northwest Passage Drive Expedition (NWPDX)
Kugluktuk to Cambridge Bay, April 2009

Moon-1 Rover: HMP Northwest Passage Drive Expedition(NWPDX)

Sampling Protocols



Culturing Results on R2A

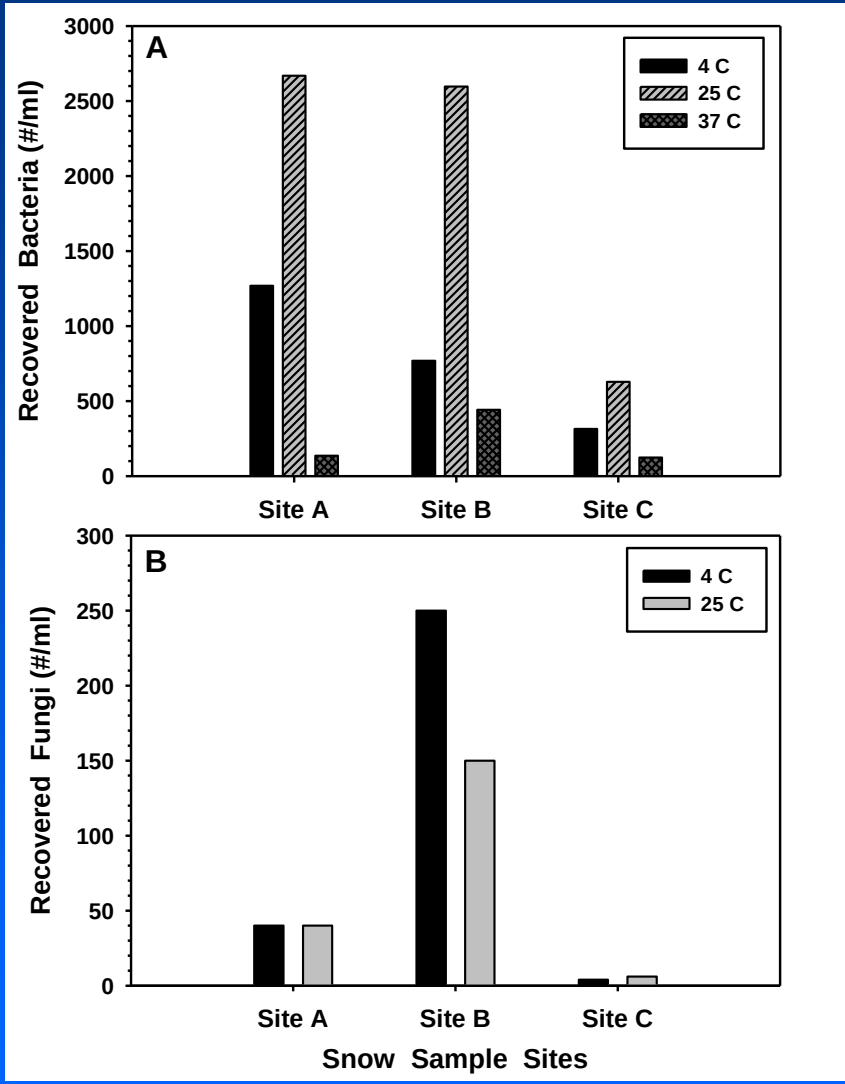


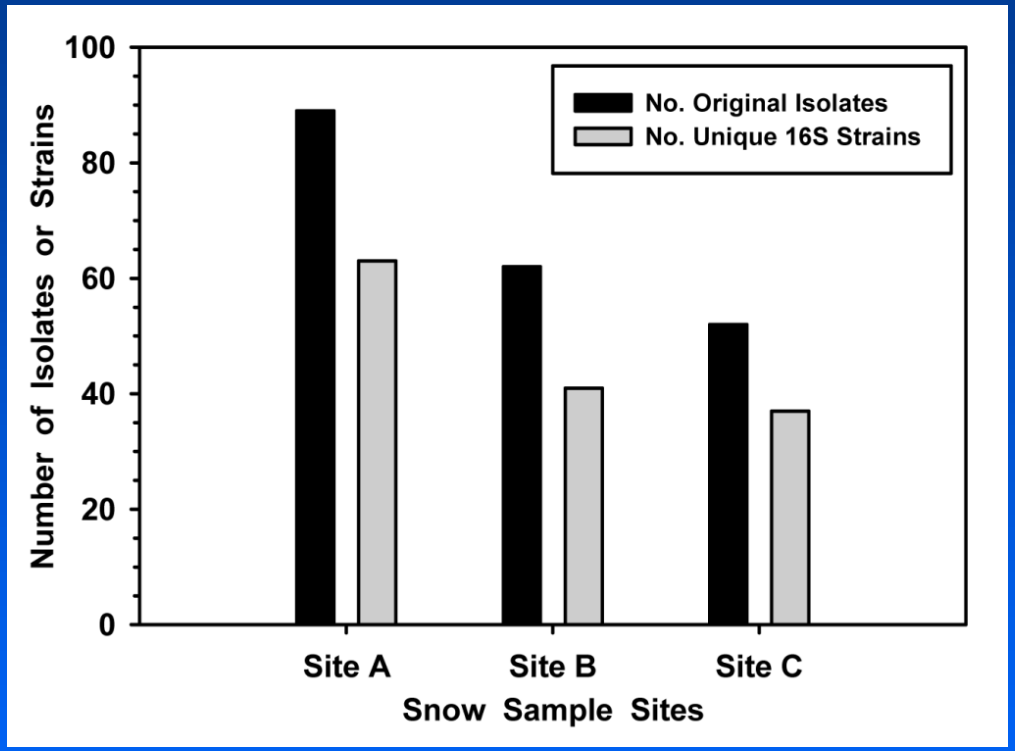
Interior Okarian rover samples.

Exterior snow samples.

Schuerger and Lee, 2015, *Astrobiology*, in review.

Population Dynamics within the *Moon-1* Rover





Schuerger and Lee, 2015, *Astrobiology*, in review.

Fungal Species Recovered from Interior of *Moon-1* Rover

Taxonomy with 18S contigs in current study[1]	Strain No. current study[2]	GenBank accession No. current study	Source location for NCBI closest match strain[3]	NCBI closest match accession No.	NCBI closest match	Number of isolates (sites)
Alternaria botrytis	A2F-4c-8	JX470350	aerosols, Sweden	AF548106	0.995	1(A)
Alternaria cheiranthi	B2F-25c-3	JX456605	plant debris, CA, USA	AF229508	0.997	1(B)
Aspergillus fumigatus	B1F-25c-2	JX456606	China	FJ560718	0.991	1(B)
Aspergillus oryzae	B1F-25c-2c	JX470334	China	HM064501	0.985	1(B)
Chaetomium globosum	C2F-4c-1	JX470335	China	JN639019	0.997	1(C)
Cladosporium cladosporioides	A2F-4c-1	JX470336	South Africa, China	AY251093	0.998	1(A), 5(B)
Cochliobolus lunatus	B1F-25c-6	JX470339	*Echinochloa* pathogen, China	DQ337381	0.996	1(B)
Geomyces destructans	A2F-4c-9	JX470340	bat pathogen, France	GQ489025	0.999	3(A), 1(C)
Geomyces pannorum	A2F-4c-10	JX470341	soil, Antarctica	AY129548	0.998	1(A)
Neophaeosphaeria filamentosa	C2F-25c-2	JX470342	USA	AF250825	0.999	2(C)
Penicillium expansum	B2F-4c-4	JX470343	human food, China	GU561988	0.999	2(B)
Penicillium freii	A2F-25c-1	JX470344	Denmark	AJ005446	0.999	2(A), 3(B)
Phoma macrostoma	A2F-25c-3	JX470346	plant leaf, Japan	AB454217	0.995	1(A)
Pleospora herbarum	B1F-25c-6b	JX470347	Oregon	DQ767648	0.993	2 (B)
Tetracladium maxilliforme	A2F-4c-5	JX470348	lake water, Canada	EU883429	0.992	1(A)
Thelebolus microsporus	A2F-4c-11	JX470349	soil, Antarctica	AY942191	0.998	1(A)

16 unique fungal taxa isolated from within the Moon-1 samples.

Schuerger and Lee, 2015, *Astrobiology*, in review.

Bacterial Species Recovered from Interior of *Moon-1* Rover

Taxonomy with 16S contigs in current study[1]	Strain No. current study[2]	GenBank accession No. current study	Source locations for NCBI strains closest match[3]	NCBI accession No. closest match	NCBI closest match	Number of isolates (Sites)
Aeromicrobium tamlense	C1-37c-2	JX517204	dried seaweed, South Korea	DQ411541	0.983	1(C)
Arthrobacter agilis	A2-4c-5	JX517205	groundwater, South Korea	EU730943	0.987	1(A)
Arthrobacter flavus	A2-4c-14	JX517206	pond water, Antarctica	FR691390	0.991	1(A)
Arthrobacter sp.	A2-25c-5	JX517207	ice/snow, Antarctica; permafrost, Norway	DQ341415	0.986	2(A), 1(B)
Arthrobacter sulfonivorans	A2-4c-15	JX517208	glacial sediments, Svalbard	FM955888	0.995	3(A)
Bacillus licheniformis (B1512R)	A1-25c-5	JX517218	fermented fish, China, India, & South Korea	JX025165	0.999	2(A), 3(B)
Bacillus megaterium	A1-25c-21	JX517219	JPL cleanroom, CA, USA; rhizosphere, China; desert granite, AZ, USA	AY030338	0.999	2(A), 2(B)
Bacillus nealsonii	A2-37c-15	JX517220	plant debris, China	FJ544393	0.999	1(A), 1(B)
Bacillus niacini (B1512R)	A2-37c-23	JX517221	soil, India	GU339292	0.991	1(A)
Bacillus pumilus	A1-25c-19	JX517223	potassium mine, China; JPL &	GU332600	0.999	2(A), 2(B),
Bacillus simplex	A1-25c-12	JX517225	plant leaves, roots, alpine grass, China; desert granite, AZ, USA; Arctic Ocean	FJ999940	0.999	4(A), 2 (B)
Bacillus sp.	A2-37c-20	JX517226	JPL cleanroom, CA, USA; ocean water, Japan; desert granite, AZ, USA; uranium mine, Germany	AY030333	0.998	4(A), 4(B), 3(C)
Bacillus thuringiensis	A1-25c-14	JX517227	Jatropha endophyte, Singapore	JQ659733	1.000	3(A)
Bacillus weihenstephanensis	A2-25c-6b	JX517228	forest soil, France	CP000903	1.000	1(A
Breivbacillus brevis	B1-37c-14	JX517229	plant compost, Spain	EF079071	0.998	1(B)
Brevibacillus borstelensis	A1-37c-13	JX517230	fermented soybean sauce, South Korea	FJ982663	0.999	2(A)

42 additional bacterial taxa including *Kocuria*, *Microbacterium*, *Paenibacillus*, *Planococcus*, *Sporosarcina*, and *Staphylococcus* spp.

Schuerger and Lee, 2015, *Astrobiology*, in review.

1 Fungus & 1 Bacterium Recovered from Snow Samples

Taxonomy 16S or 18S with contigs in current study[1]	Strain No. current study[2]	GenBank accession No. current study	Source location for NCBI closest match strain	NCBI closest match accession No.	NCBI closest match	Number of isolates
Aspergillus fumigatus	B6F-25C-1	JX517279	Plant debris, China	FJ560718	0.991	1(B)
Brevibacillus agri	A4-25C-2	JX517278	brick wall, China	GQ927168	0.998	1(A)

Schuerger and Lee, 2015, *Astrobiology*, in review.

17 Biocidal or Inhibitory Factors on the Surface of Mars

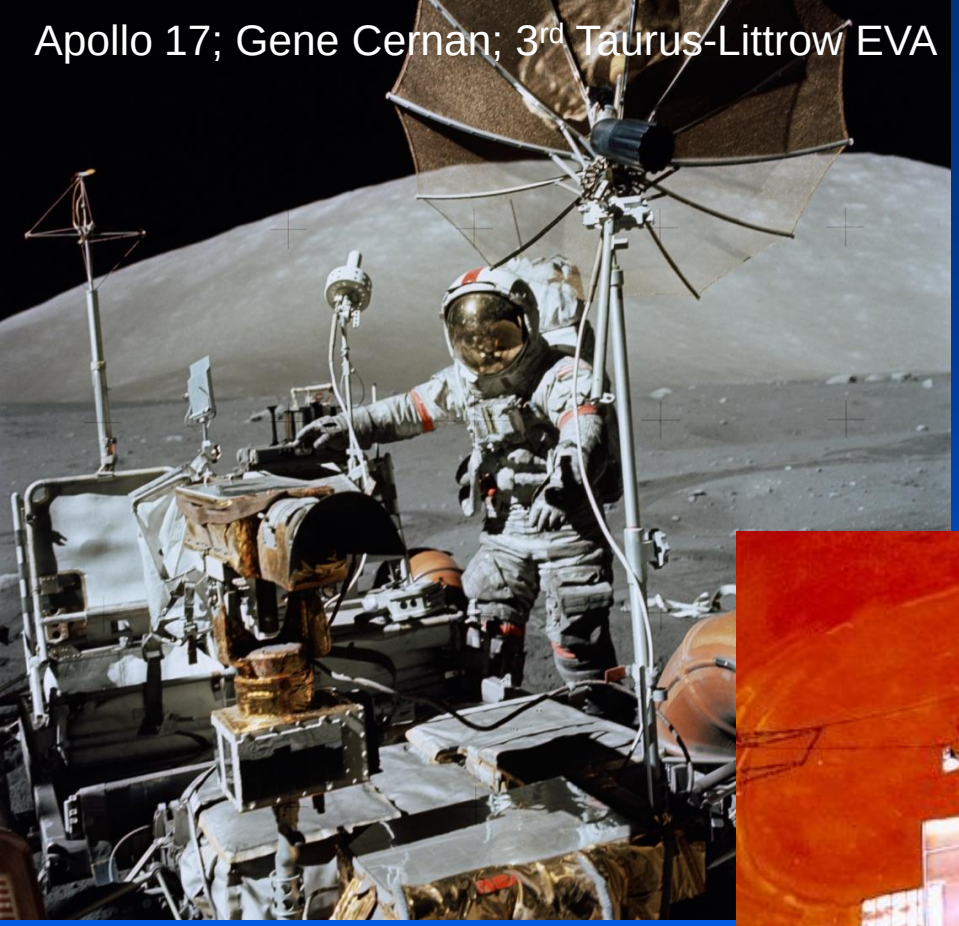
(1) solar UV irradiation
(2) extreme desiccating conditions
(3) low pressure
(4) anoxic CO_2-enriched atmosphere
(5) low temperature
(6) high salts levels [e.g., $MgCl_2$, NaCl, $FeSO_4$, and $MgSO_4$] in surficial soils
(7) lack of defined energy source free of UV irradiation
(8) no sources of available nitrogen and carbon
(9) no obvious redox couples for microbial metabolism
(10) galactic cosmic rays
(11) solar particle events
(12) UV-glow discharge from blowing dust
(13) solar UV-induced volatile oxidants [e.g., O_2^-, O^-, H_2O_2, O_3]
(14) globally distributed oxidizing soils
(15) high concentrations of heavy metals in martian soils
(16) acidic or alkaline conditions in martian soils
(17) perchlorates in some soils

(Schuerger et al., 2013, *Astrobiology*, 13, 115-131.)

Implications for Human Exploration of Mars

Conclusions:

1. Very low microbial dispersal from the *Moon-1* rover on to pristine snow during the NWPDX traverse.
2. Dispersal away from human habitats and rovers on Mars may be low to extremely low during exploration.
3. Although the Arctic is a harsh terrestrial environment, at least 17 biocidal or inhibitory factors are likely active on the surface of Mars.



Implications for Human Exploration of Mars

4. Dust covered or buried surfaces are likely to protect embedded terrestrial microorganisms, and niches in buried sites must be characterized.